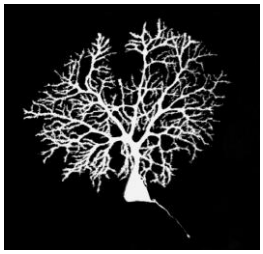
Computations neurons perform

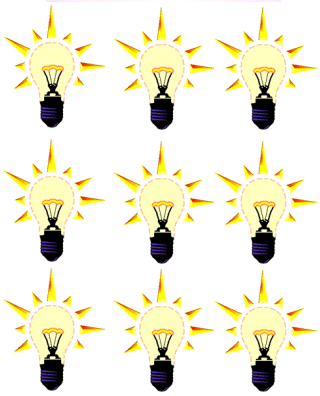


Differences between brains and computers

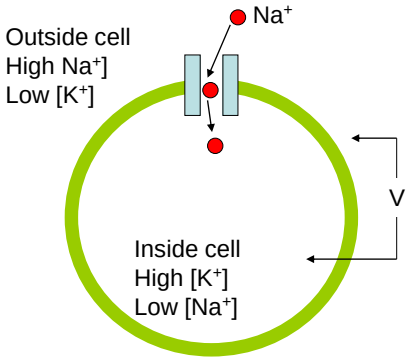
"Clock speed" ~1kHz

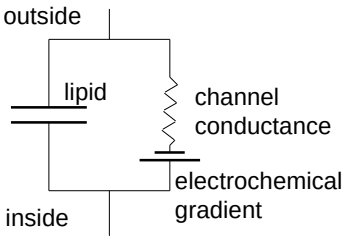
Processing rate limited by energy use

~4GHz



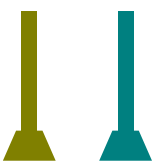
Neurons code information as transmembrane voltage changes

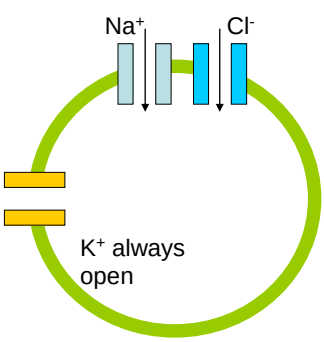




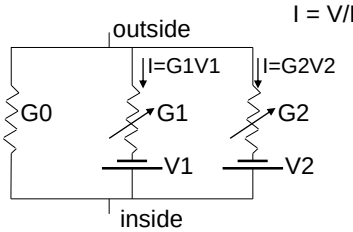
[K+] gradient sets resting potential of -70mV
Here I will measure voltages from the RP
(denoted zero)

Analogue coding of information





I = V/R = GV



V=IR = I/G

$$V = \frac{G1V1 + G2V2}{G0 + G1 + G2}$$

If G0>> G1, G2 — if V1 and V2 same

$$V = \frac{G1V1 + G2V2}{G0} = \frac{(G1 + G2)\,V1}{G0}$$

This allows addition or subtraction) of signals (coded α G)

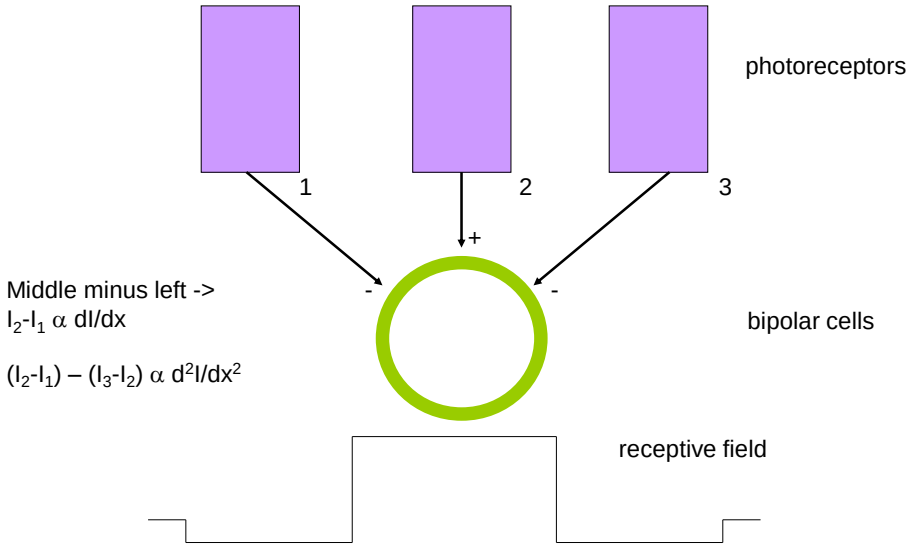
If G2>> G1, G0 and V2=0 (shunting inhibition)

$$V = \frac{G1V1}{G2}$$ This allows division of signals

Two divisions in a row gives multiplication

E.g. if G2 is proportional to 1/G3, then V is proportional to G1G3

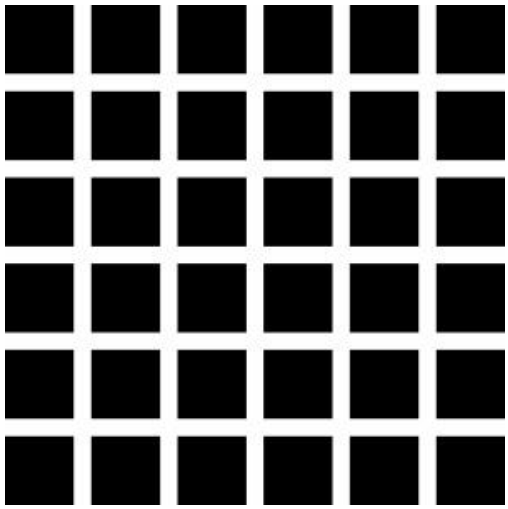
Spatial filtering by synaptic convergence



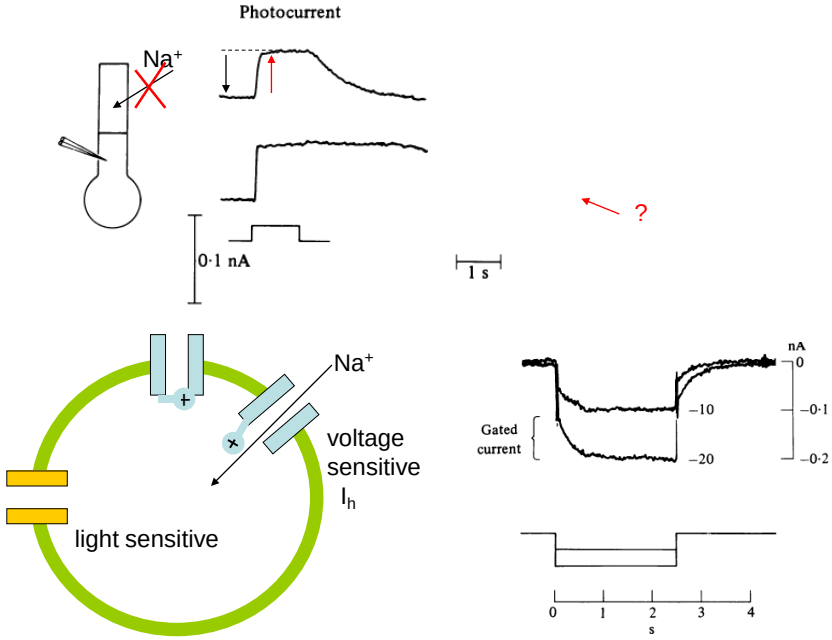
Middle minus left ->
$I_2 - I_1 \alpha\ dI/dx$

$(I_2 - I_1) - (I_3 - I_2) \alpha\ d^2I/dx^2$

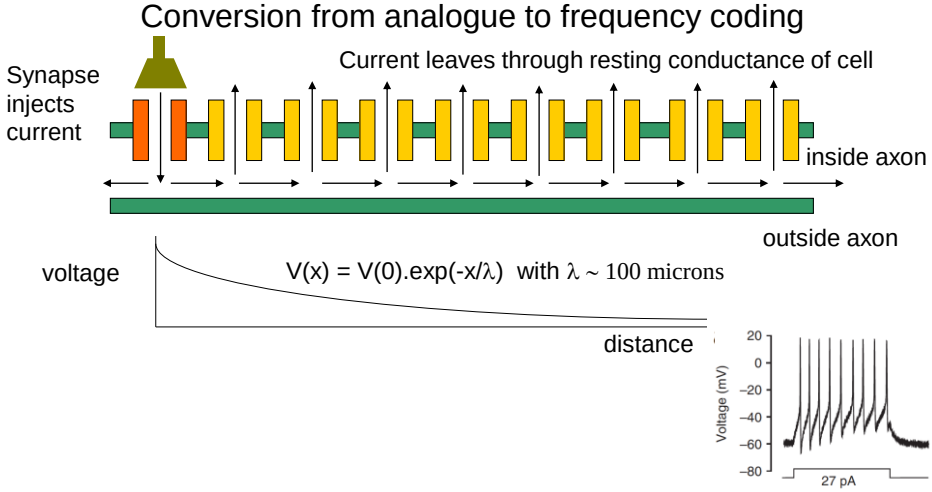
Lateral inhibition: the Hermann grid



Temporal filtering by voltage-gated channels

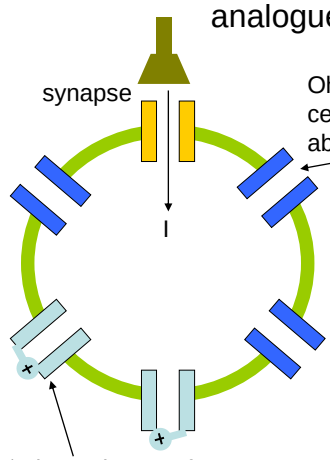


Conversion from analogue to frequency coding

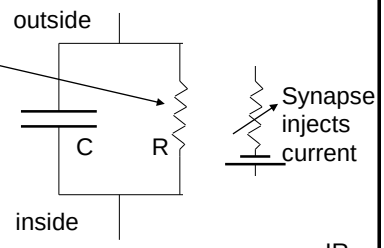


Code information as frequency of APs, all of which are same size

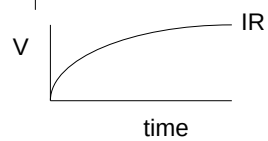
Mathematical operations inherent in converting from analogue to frequency coding



Ohmic channels set cell resistance in absence of input



$V = IR\,[1-\exp(-t/RC)]$



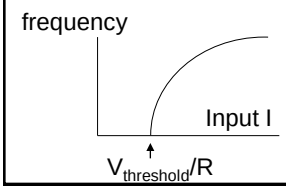
Na^+ channels open for $V > V_{threshold}$

If $IR < V_{threshold}$ no action potential

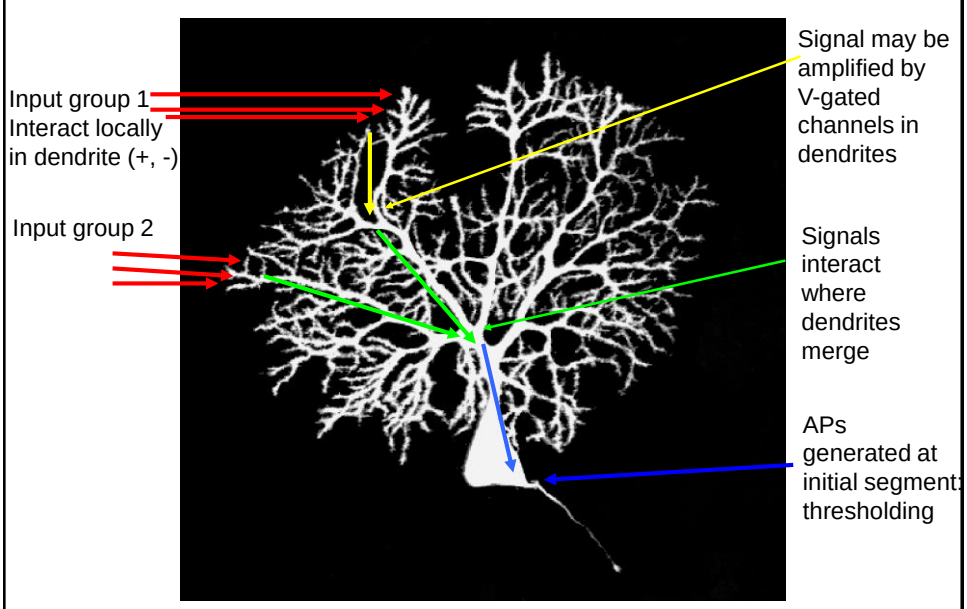
If $IR > V_{threshold}$ $V_{threshold}$ is reached at a time when

$V_{threshold} = IR[1-\exp(-t/RC)]$

So Frequency $= 1/t = 1/[RC.\log_e(1/1-V_{threshold}/IR))$
Implies thresholding and non-linear increase with I



Spread of signals through the dendritic tree



There are lots of separate opportunities for information processing in the dendritic tree